The Application of Low-pressure Backwashing Filter in Oilfield Produced Water Disposal

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Abstract

At the present liquid disposal process during the oilfield producing, filtration is essential, and its effect is determined by the quality of backwashing. In order to solve the problems of high pressure in backwashing, filter material loss and difficult regeneration in traditional filtration device, low-pressure backwashing filter is designed by means of the filtration structure improvement and operation parameter optimization on the basis of backwashing principle. The pilot tests in Daqing Oilfield show that by using low-pressure backwashing filter, the backwashing pressure can be maintained between 0.03 MPa and 0.08 MPa, the backwashing can be realized by filtered water in tank and the filter material regenerates well. The quality of the filtered polymer-containing produced liquid is improved obviously, and the average oil content is less than 10 mg/L, and the suspended solids content is less than 20 mg/L, meeting the reinjection standard of reservoirs with moderate and high permeabilities.

Keywords

Produced Liquid Disposal; Filter; Backwashing; Daqing Oilfield

Introduction

In oilfield development, produced water increases annually as water content rises. Taking Daqing Oilfield (China) as example, more than 30 million tons of produced water is made every year. Without disposal, the discharged produced water will pollute the environment, cause serious economic losses, and even threaten human life safety. The most effective method to solve this problem is to reinject the treated produced water into reservoirs. Obviously, the reinjection water requirement changes with the different permeabilities of oil reservoirs and the disposal processes of produced water are varying accordingly. However, in the various disposal processes, filtration is fundamental.

Presently, the produced water disposal process used in oilfield holds many advantages, such as high oil removal efficiency, stable quality of treated water, and convenient maintenance and management. However, with the popularization and application of polymer EOR, chemical agent concentration of produced water increases continuously. So, the absorbility of filter material to oil and suspended solids is on the increase, and the relative density of filter material with oil is decreased. Under the conventional backwashing speed, the increase of backwashing pressure, loss and incompletely regeneration of filter material are caused by serious filter material expansion. Then the oil and suspended solids content in the filtered produced water are difficult to satisfy the standard, influencing the filtration effect. Therefore, the study and application of low-pressure backwashing filtration technology is extremely essential.

Principle and Devices of Produced Water Filtration

Filtration Process

As the fundamental process of produced water disposal in oilfield, filtration has three functions as follows: First is synergistic effect. Oil and suspended solids are removed at the same time as they stick together. Second is coarse graining effect. The particle sizes of oil drops are enlarged by filter material, and then adhered to suspended solids. Third is the filter material itself that has the interception and absorption effect to oil. Therefore, oil and suspended solids in

oilfield produced water can be removed efficiently through the filtration process.

Backwashing Process

Filter bed is composed of filter material layer and supporting layer in filter tank. During the filtration, filter bed porosity is reduced by impurities removed from the produced water and stored on filter bed. Consequently, the filter tank needs regular backwashing. In this way, the pollutants adhered to the filter material particles are peeled and discharged from the filter tank with deposits, making the filter material effective and ensuring the filtration quality.

Filtration Device

In oilfield produced water disposal, filter can be divided into pressure type and gravity type by motive power source in filtration, and according to the filter medium, it can be classified as quartz sand filter, walnut shell filter, multi-layer filter, fiber ball filter and so on. Filter tank is mainly composed of the tank body, filter material layer, supporting layer, water distribution system, drainage system and stirring system. Furthermore, pipelines and valve system are also designed to satisfy the requirements of filtration and backwashing. Walnut shell, which has better lipophilicity, strong interception capacity, lighter texture and low backwashing energy consumption, is widely used in oilfield produced water first stage filtration to mainly remove the oil. In second stage filtration, the quartz sand is widely used to remove the suspended solids in produced water, due to its small particle size and strong capability of removing tiny suspended solids.

Principle and Structure of Low-pressure Backwashing Filter

Design Principle and Basic Structure

The filtration efficiency of low-pressure backwashing filter is improved on the basis of low-pressure steady-flow backwashing licensed technology. Key of this technology is to reduce the expansion rate during the backwashing, and control the expansion height of filter bed efficiently. In the meanwhile, by combining with different stir ways, filter material can be cleaned more completely, and its assimilative capacity can be enhanced. In this way, the quality of the treated water will satisfy the standard.

According to Ergun theory, the relationship among expansion height of filter bed, backwashing fluid flow viscosity and density of filter material particles is shown as follow:

$$\begin{cases} L_{\exp} = \Delta P_{\exp} / [(1-\varepsilon_{\exp}) \cdot g \cdot (\rho_s - \rho_1)] \\ U_{s\exp} = R \cdot [\varepsilon_{\exp}^3 / (1-\varepsilon_{\exp})] \\ U_{s\exp} = Q_{\exp} / A \end{cases}$$

In which: L_{exp}—— Expansion height of filter bed

ρ_s—— Density of filter material particles

$U_{s\,exp}$—— Backwashing intension

On the basis of the formula, the expansion of filter bed is proportional to backwashing intension, and it is inverse proportional to density of filter material particles. After filtration, oil and polymer are adhered to the filter material, especially on its upper layer, causing relative decrease of filter material density. During the backwashing, when light filter material (usually is walnut shell) is filled into the tank, the spaces among filter material would be enlarged as the stirring paddle started. The two factors make the expansion rate of filter material rise fast, and the water distribution screen pipe is clogged by the light rising filter material with the oil and polymer. Then the pressure increases and backwashing water flow decreases sharply, and as a result, backwashing is not efficient. When heavy multiple medium filter material is filled, strong intensity backwashing is needed to clean the filter material, for its relative larger density and harden phenomenon. However, strong backwashing intensity can also cause the results above. Therefore, in order to avoid high pressure and clean filter material completely, the key is to decrease expansion rate of filter material.

Filter tank structure and process are elaborately designed to solve the problems of the existing filter. In order to decrease the high pressure in backwashing and clean the filter material completely, several equipments such as stereoscopic water distributor and anti-swelling plate have been added in the tank, as shown in Fig. 1.

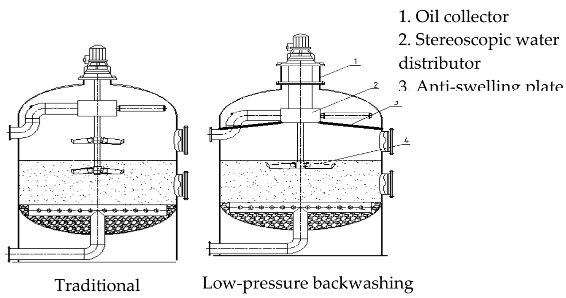

FIG. 1 TRADITIONAL FILTER AND LOW-PRESSURE BACKWASHING FILTER

Structure Improvement

1) Improved Scheme

In the filter structure improvement, anti-swelling plate is added between filter screen pipe and stirring paddle, and sweeping device is designed under the plate. The anti-swelling plate can prevent the filter material from entering into the dead corners between the screen pipe and tank top during the backwashing. On one hand, the sweeping device can avoid the filter material adhering to the screen pipe; on the other hand, filter material is gathered to the lower part of the tank, and then the filter material can be scattered sufficiently by stirring paddle, peeling off the oil adhered to the upper filter material. Oil collectors are designed on the tank top. When oil enters into the tank top, it is discharged into the oil collector directly by pipelines under the operation of sweeping device. Then the oil pollutants can be cleaned in time and screen pipe will not clogged by the falling oil from the tank top. On bottom, permeable stainless steel gravel plate is added, and the supporting function loss of the gravel in backwashing supporting layer is avoided, as it is scoured by strong water flow.

2) Water Distribution System Improvement

On the basis of original single horizontal water distributor, vertical water distribution screen pipe is added, and the stereoscopic water distributor is formed. Then the water is well distributed. At the same time, impurities in backwashing water can be discharged in time and the pipe clog caused by the falling oil from tank top can be prevented efficiently.

3) Stirring System Improvement

By improving paddle structure, adjusting paddle size, shape and angles among paddles, the flow field structure is changed when the paddles are spinning. In addition, the rising speed of filter material is slowed down, the stirring scope is expanded, and the stirring dead corners are reduced. Furthermore, the distance between paddle and water distribution screen pipe is shortened from 0.7 m to 0.5 m, then the intensity of stirring the upper filter material is enhanced. Stirring paddle electrical machine is replaced to change the linear velocity of paddle, and then the filter material can be less destroyed.

4) Operation Parameter Design

In order to develop the potential of low-power backwashing filter, and further improve the backwashing effect, backwashing operation parameters are optimized. The backwashing of filter material is essential when the filter works 23.5 hours and the backwashing agent must be added before the stirrer start. It needs 720 minutes to stir with agent and the backwashing time is set to be 30 minutes. Before normal operation, 10 minutes is needed after backwashing. In addition, backwashing pressure is optimized between 0.03 MPa and 0.08 MPa, the backwashing intensity is controlled between 7.0 L/(s.m^2) and 9.7 L/(s.m^2), the instantaneous flow rate of backwashing is 180~280 m^3/h, water consumption of backwashing is 100~150 m^3/h, and the backwashing period is 24~36 h. Pilot test indicates that the backwashing effect is obvious by the optimized parameters, and the regeneration effect of filter material is desirable, providing reliable guaranty for filtration.

The Application Effect of Low-pressure Backwashing Filter in Produced Water Disposal

In chemical flooding test area of Daqing Oilfield, the application effect of low-pressure backwashing filter is studied, and the improvements of its water quality and backwashing pressure are analyzed.

Water Quality Analysis

1) Reinjection Water Quality Standard

Reinjection water quality standard changes with the different permeabilities of each oilfield, as shown in Table 1.

TABLE 1 REINJECTION WATER QUALITY STANDARD IN OILFIELDS

Main Projects	**Recommended Indexes**				
	Permeability (μm²)				
	<0.02 (Extra Low Permeability Reservoir)	**0.02~0.1 (Low Permeability Reservoir)**		**0.1~0.6 (High Permeability Reservoir)**	
		Water Flooding	**Polymer Flooding**	**Water Flooding**	**Polymer Flooding**
Oil Content (mg/L)	≤5.0	≤8.0	≤5.0	≤20.0	≤20.0
Suspended Solids (mg/L)	≤1.0	≤3.0	≤5.0	≤10.0	≤20.0
Particle size ofsuspended solids (μm)	≤1.0	≤2.0	≤2.0	≤3.0	≤5.0

2) Disposal Effect of Low-pressure Backwashing Filter

Two filter tanks, marked as 1# and 2#, are selected and transformed by low-pressure backwashing technology. Then the produced water disposal effect is analyzed. The results indicate that the median particle sizes of the two tanks are both under 1.0, and in the 1# tank, the oil content and suspended solids can be maintained under 5 mg/L and 10 mg/L, respectively. In 2# tank, the data of oil content in filtered water are mainly less than 10 mg/L, except some individual data influenced by the water quality, and the suspended solids content is stabled under 20 mg/L. Therefore, the reinjection water standard of reservoirs with moderate and high permeabilities is satisfied by using the low-pressure backwashing filter, and the effect is obvious.

Backwashing Pressure

The two filter tanks are transformed and tested. The backwashing time variation with pressure is shown in Fig. 2.

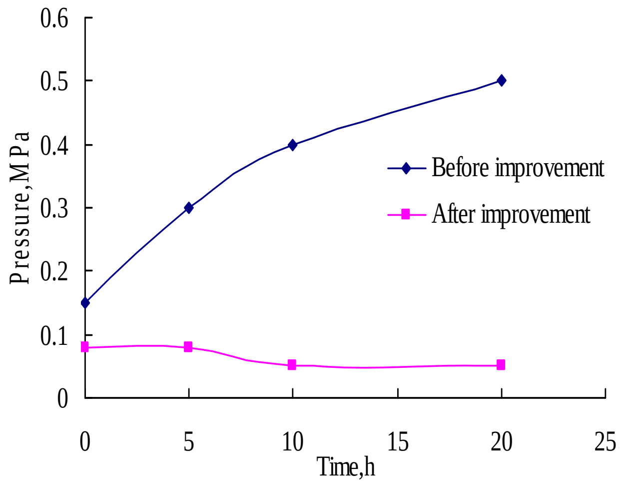

FIG. 2 THE RELATIONSHIP BETWEEN TIME AND PRESSURE OF BACKWASHING

The result shows that before improvement, the pressure increase with the passage of backwashing time, which explains that the backwashing is not efficient. However, when the low-pressure backwashing filter is used, the pressure is between 0.03 and 0.08 MPa, and the flow remains relative stable. In addition, the backwashing can be realized by the filtered water in the tank without pump, then the backwashing operation procedure is simplified and the electric energy is saved.

Conclusions

Low-pressure backwashing filter process is designed by improving the filtration structure and optimizing the operation parameters. The removal efficiency of oil and suspended solids in the produced water are enhanced, and the water after disposal will satisfy the reinjection standards of reservoirs with moderate and high permeabilities. Furthermore, the backwashing pressure can be maintained between 0.03 MPa and 0.08 MPa, and then the facilities in the tank are well protected. In addition, the backwashing can be realized by the filtered water in the tank, and the economic benefit is enhanced. This technology is significant to the advanced disposal and reinjection of oilfield produced water, and the application prospect is broad.

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REFERENCES

Guo Jinlong, Meng Jun, Li Guiping., "Physicochemical Interaction and Its Influence on Deep Bed Filtration Process." Journal of Environmental Sciences (2004): 297-301.

Guo J.L., Wang Y.L., Liu R.X., "Calculation Model of Uniform Media Filtration Capacity." Colloids Surf.A (2002):237-245.

Liu Shumeng, Zhang Zhenjia, Jiang Minghu., "Treatment of ASP Produced Water with Hydrophilic Fibre Ball Filtration." Journal of Harbin Institute of Technology (2007):837-841.

Leverenz H.L., Tchobanoglous G., Darby J.L., "Clogging in Intermittently Dosed Sand Filters Used for Wastewater Treatment." Water Research (2009):695-705.

O. Caliskaner, G. Tchobanoglous., "Optimization of Compressible Medium Filter for Secondary Effluent Filtration." Water Practice and Technology (2009):1-8.

Patrick B. Tsang, Christopher J. Martin, "Economic Evaluation of Treating Oilfield Produced Water for Potable Use." SPE86948 (2004): 458-469.